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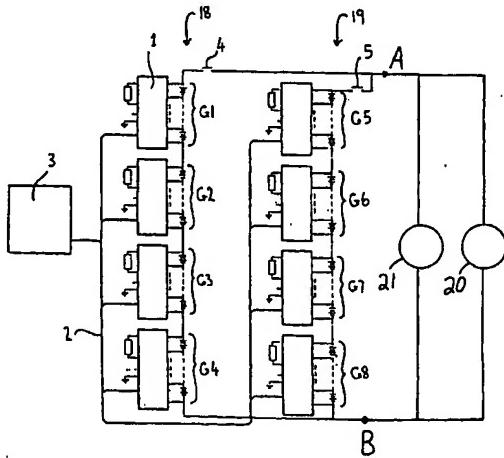
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(54) Title: BATTERY MANAGEMENT UNIT, SYSTEM AND METHOD



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(57) Abstract: A battery management unit and system for managing the state of charge of cells or batteries (B1-B10). Each battery management unit (1) measures cell or battery terminal voltage and provides this information to a central controller (3) via a communication medium (2). Each battery management unit (1) monitors a plurality of batteries (B1-B10) and can selectively charge a selected battery (B1-B10) via a charger (7) and switch circuit (8, 17) or can selectively discharge a selected battery (B1-B10) via a load (10) and switch circuit (8, 17) under the control of a controller (6). The controller (6) may control charging and discharging in accordance with measurements from voltage sensors (15a-j) or may convey information from a voltage sensors (15a-15j) to the central controller (3) and receive charging and discharging commands from the central controller (3). Charging and discharging is controlled to maintain all batteries within a desired state of charge range. The central controller (3) may selectively connect a main charger (20) or generator (21) to a bank of batteries associated with a battery management unit (1).

AP2

**Battery Management Unit, System and Method****Field of the Invention**

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The invention relates to battery management systems and in particular to a system and method for managing the operation of batteries in electric vehicle applications.

**Background to the Invention**

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Electric vehicles are known in the art. They include one or more battery that supplies energy to one or more electric motors that in turn provide motive force to the vehicle. Each battery is generally charged overnight for use during the day.. In these vehicles each battery can undergo regular deep cycling of its state of charge and thus each 15 battery life expectancy is typically short. It is undesirable to discharge a battery too far as this also shortens battery life.

Hybrid electric vehicles are known. One type of hybrid vehicle includes an auxiliary power unit that can be used to generate energy during use of the vehicle. This energy 20 can be used to supplement battery energy or to charge the battery. With the availability of an auxiliary power unit within the vehicle it is desirable to have a battery management system which regulates battery and auxiliary power unit operation and avoids overcharging of the batteries, which can reduce battery life.

25 A number of battery management systems are known, however they generally only perform any real control during overnight charging. During use the auxiliary power unit is often run continuously at a predetermined and fixed power output. This can result in overcharging of the battery. Alternative schemes only run the auxiliary power unit if the battery voltage, or state of charge, falls below a predetermined level. This does not 30 overcome problems with state of charge cycling.

In the publication "Distributed VRLA Battery Management Organisation with Provision for Embedded Internet Interface" (Anbuky et al.) IEEE, Telecommunications Energy Conference (INTELEC 2000) there is disclosed a distributed system for gathering and

storing state of charge information. Data analysis is distributed rather than centralised and there is no disclosure of a charging strategy to achieve state of charge equalisation.

WO 99/01918 discloses a battery management system in which individual cells may be  
5 selectively connected to a single cell battery charger or a variable load bank. However, connection to the single cell battery charger or variable load link is simply for determining the capacity of each battery rather than for performing any equalisation of the state of charge of batteries.

10 US5701068 discloses a battery management system in which each battery has an associated battery module for monitoring the battery and charging the battery. This is an expensive and complex system.

US6043628 discloses a battery management system in which a bypass arrangement is  
15 provided for each battery to reduce overcharging of selected batteries whilst allowing the remaining batteries to be charged. This requires an individual module with a bypass resistor arrangement for each cell and does not allow the selective charging of selected batteries.

20 US6078165 is a system for monitoring and charging only. No discharge capability is disclosed.

EP0798839A2 discloses a battery management system in which an individual battery module is required for each battery making it expensive and complex.

25 It is an object of the present invention to provide a battery management system that controls battery operation in a hybrid electric vehicle to optimise battery performance and extend the battery life.

30 It is a further object of the present invention to provide a battery management system for hybrid electric vehicles that overcomes, or at least ameliorates, the above mentioned problems with the prior art.

The above objections are to be read disjunctively with the object of at least providing the public with a useful alternative.

Summary of the Invention

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According to a first aspect of the invention there is provided a battery management unit for managing the state of charge of a plurality of cells or batteries connected thereto including:

- 10        a state of charge sensor for measuring the state of charge of the cells or batteries;
- a charger for charging a cell or battery;
- a discharger for discharging a cell or battery;
- a controller which receives state of charge information from the state of charge sensor and selectively connects the charger or the discharger to a cell or battery to dynamically maintain the state of charge of the cells or batteries within a predetermined range.

According to a further aspect of the invention there is provided a method of charging and equalising the state of charge of a plurality of cells or batteries comprising the steps 20 of:

- i        simultaneously charging the cells or batteries by a main charger; and
- ii        maintaining the charged state of individual cells or batteries during charging by selectively charging or discharging cells having a state of charge outside of a prescribed range.

According to another aspect the invention provides for a system for managing the operation of a battery comprising two or more series connected cell or battery groups including:

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two or more battery management units connected to an associated battery group, the local apparatus including a local processor operable to measure one or more cell and/or ambient variable parameters and control charge and/or discharge of the one or more cells or batteries within the group; and

a central processor in communication with two or more local processors; and wherein,

5       the central processor is responsive to one or more cell and/or ambient variable parameters to dynamically control the supply of energy to the two or more series connected battery groups; and/or local processors are responsive to one or more cell and/or ambient variable parameters or transmitted control data to control charge and/or discharge of the one or more cells or batteries within a group substantially independently of the supply of energy to the two or more series  
10      10 connected battery groups.

Preferably the system includes a main charger, the central processor dynamically controlling the supply of energy to the two or more series connected battery groups via the main charger.

15      15 Preferably the system includes an auxiliary power unit, alternatively the central processor dynamically controlling the supply of energy to the two or more series connected battery groups via the auxiliary power unit. More preferably the central processor either continuously or periodically estimates the energy removed from the two  
20      20 or more series connected battery groups and dynamically varies the auxiliary power unit output power to substantially maintain a substantially constant state of charge of the two or more series connected battery groups.

According to a first particular aspect the invention provides for a system for managing  
25      25 the operation of a battery comprising two or more series connected cell or battery groups including:

two or more battery management units, each connected to an associated battery group, the unit including:  
30      30        a local charger,  
              a local discharger,  
              a switch for electrically connecting the local charger or local discharger individually to one or more cells or batteries within the group,

- sensors for measuring one or more cell and/or ambient variable parameters within the group, and
- a local processor in communication with the local charger, discharger, switch, and sensors and being operable to control the charger, discharger and switch;
- 5 a main charger for supplying energy to the two or more series connected battery groups; and
- 10 a central processor in communication with two or more units and the main charger and being responsive to battery condition to manage operation of the battery.
- 15 Preferably the system includes a common communication medium, the central processor and local processors being connected to the common communication medium and each processor being operable to communicate with another processor or simultaneously to all processors connected to the medium.
- 20 Preferably the central processor is in communication with one or more local processor to receive information about one or more cell and/or ambient variable parameters and being responsive to said information to manage operation of the battery.
- 25 The central processor may be responsive to individual cell and/or variable parameters to manipulate the supply of energy from the main charger means to the two or more series connected battery groups, and/or transmit control data to one or more local processor dictating control of the one or more cells or batteries within the groups. Alternatively, the central processor may manipulate the supply of energy from the main charger to the two or more series connected battery groups and the local processor means may be responsive to reference information to control of the one or more cells or batteries
- 30 within the groups.
- Preferably the local processor can manipulate the supply and/or removal of energy to/from an individual cell or battery within its group independent of operation of any other group or the main charger. It is envisaged that preferably, although not

exclusively, the switch is a multiplexer adapted to connect either the local charger or local discharge to any individual cell or battery within the group, the multiplexer being manipulated by the local processor.

- 5 According to a further aspect the invention provides for a method for managing the operation of a battery comprising two or more series connected cell or battery groups including:

10 connecting a battery management unit to each of two or more battery groups, each said unit including:

a local charger,

a local discharger,

a connector for electrically connecting the local charger or local discharger individually to one or more cells or batteries within the group,

15 local sensors for measuring one or more cell and/or ambient variable parameters within the group, and

a local processor in communication with the charger, discharger, connector, and sensor and being operable to control operation of said means and the one or more cells or batteries within the group;

20

connecting a main charger to the battery;

providing a central processor in communication with the unit; and wherein

25 periodically or continuously the two or more unit measure one or more cell and/or ambient variable parameters of the two or more series connected battery groups and communicate said parameters to the central processor; and

30 relating said parameters to reference criteria and in response the central processor dynamically controls the supply of energy to the two or more series connected battery groups; and/or local processor manipulates the charge and/or discharge of the one or more cells or batteries within a group substantially independently of the supply of energy to the two or more series connected battery groups

Preferably the central processor initiates the measuring of one or more cell and/or ambient variable parameters and the communication of said parameters to the central processor.

5

Preferably the central processor initiates and terminates the charge or discharge of one or more cells of batteries within a group.

10 Preferably the system includes a main charger, the central processor dynamically controlling the supply of energy to the two or more series connected battery groups via the main charger.

15 Preferably the system includes an auxiliary power unit, alternatively the central processor means dynamically controlling the supply of energy to the two or more series connected battery groups via the auxiliary power unit. More preferably the central processor either continuously or periodically estimates the energy removed from the two or more series connected battery groups and dynamically varies the auxiliary power unit output power to substantially maintain a substantially constant state of charge of the two or more series connected battery groups.

20

According to a further aspect the invention provides for a hybrid electric vehicle including a battery management system or method as hereinbefore defined.

25 Further aspects of the invention will become apparent from the following description which is given by way of example only.

#### Brief Description of the Drawings

The invention will now be described with reference to the accompanying drawings in 30 which:

**Figure 1;** illustrates a schematic overview of the hardware from a battery management system according to the invention, and

**Figure 2** illustrates a schematic overview of a remote management unit of the battery management system illustrated in Figure 1.

Description of the Preferred Example

A specific example of the invention will now be described with reference to Figures 1  
5 and 2, in which like numerals represent like integers. The invention will be described  
with reference to a particular set-up of a hybrid electric vehicle in which the battery  
comprises two parallel strings 18 and 19 of forty series connected 12-volt batteries.  
This is not critical to the invention, however, and it will become apparent to the skilled  
addressee that the invention is equally applicable to other battery configurations.

10

Referring to Figure 1, there shown is a schematic overview of the hardware from a  
battery management system according to the invention. The battery comprises eighty  
12-volt batteries configured in two parallel strings 18 and 19 of forty series connected  
12-volt batteries. Each string 18 and 19 is further divided into four groups G1-G4 and  
15 G5-G8 comprising ten series connected 12-volt batteries. According to this battery  
configuration the output voltage between Bus nodes A and B is 480-volts DC. Relays 4  
and 5 allow isolation of each 480-volt battery string 18 and 19.

In communication with each ten battery group is a battery management unit 1, which  
20 for the purpose of this description shall be referred to as a remote management unit 1.  
Each remote management unit 1 is connected to an RS485 communications medium 2,  
typically in the form electrical conductors. Also connected to the communications  
medium 2 is a central controller, typically a programmable logic controller.

25 The system also includes a main battery charger 20 and an auxiliary power unit 21,  
both of known type, connected to the DC Bus nodes A and B. The main battery  
charger and auxiliary power unit are controllable by central controller 3.

Referring to Figure 2, there is shown a schematic overview of the hardware within a  
30 remote management unit 1. Each remote management unit 1 includes a local battery  
charger 7 and discharger, in eth form of discharge resister 10, either of which can be  
electrically connected, via a multiplexer relay 8, to any one of batteries B1 to B10  
within the corresponding battery group. A relay 17 is operable to electrically connect  
either of battery charger 7 or discharge resister 10 to the common input of multiplexer

relay 8, which in turn is operable to electrically connect its common input to any one of ten outputs corresponding to the ten batteries B1 to B10. Both relay 17 and multiplexer relay 8 are controlled by a local micro-controller 6. Thus charger 7 or discharge resistor 10 can be selectively connected across the terminals of any one of batteries B1 to B10.

5

- The voltage of each battery in a group can be detected by differential amplifiers 15a to 15j. Two further differential amplifiers 16a and 16b (measuring the voltage drop across reference resistor 16c to determine current) are adapted to measure the voltage and current at the multiplexer relay 8 common input. An analogue multiplexer 9 is used to 10 combine the outputs from each differential amplifier 15a to 15j, 16a and 16b, and scale their signal inputs into micro-controller 6. In the current embodiment the differential amplifiers are designed to measure voltages in the order of 0 -16 volts which are scaled to 0 - 2.5 volts at the micro-controller 6 analogue input.
- 15 A temperature probe 11 detects the common temperature of batteries B1 to B10 in the battery group. The temperature probe 11 signal is coupled to micro-controller 6 via an analogue isolation amplifier 12.

- The micro-controller 6 can communicate with the central controller 3 via an RS485 20 interface 13 connected to communications medium 2. In the preferred embodiment the central controller 3 initiates all communications on medium 2. However, it is envisaged that in an alternative embodiment two or more micro-controllers 6 may communicate with each other.
- 25 Each remote management unit 1 includes a power supply module 14 that provides multiple voltage outputs to meet the power requirements of components within the remote management unit 1.

- By the above configuration each remote management unit 1 has the ability to measure 30 individual battery B1 to B10 voltages and the temperature of each battery group. This information is transmitted via communication medium 2 to central processor 3. The remote management unit 1 can also control local charge or discharge of any individual battery B1 to B10 within its group. This distributed data acquisition has the advantage

of reducing the overall wiring needed to detect all eighty individual battery voltages directly at the central controller 3, as well as the cost of additional controller 3 inputs.

In the preferred embodiment of the invention a number of communication transactions  
5 are envisaged that enable the central controller 3 and micro-controllers 6 from each remote management unit 1 to communicate the required information for charge management of the battery. The communication transactions are described below.

It is desirable, but not crucial to the invention, that individual battery voltages are  
10 measured simultaneously. While this is not possible within a battery group because of the use of multiplexing, it is envisaged that a remote management unit 1 will be able to consecutively sample each of its ten battery voltages within a few tens of milliseconds. To ensure that each remote measurement unit 1 is synchronised to sample voltages simultaneously a "sample battery voltages" command is issued on the communications  
15 medium 2 by the central controller 3. The remote management unit 1 also samples the group temperature at this time.

The sampled battery voltages and temperature are stored in a data table within local micro-controller 6 memory. The data table also includes status information that will  
20 identify any fault conditions such as multiplexer relay failure, charger failure and the like. The central controller 3 polls each remote management unit 1, in turn, requesting that it transmit its information data table.

With access to individual battery information it is envisaged that the central controller 3  
25 can make determinations on equalisation of individual batteries within a group. An "equalisation request" can be issued to an individual remote management unit 1 directing it to connect an individual battery to the local charger 7 or discharge resistor 10 for equalisation purposes.

30 The following discussion relates to the scheme employed by the battery management system for management of the hybrid vehicle battery. As a preliminary point, individual battery voltages are sampled and transmitted to the central controller 3 at a rate of once every second. Also, the central controller 3 recognises two modes of operation: overnight charge control and in-use control.

The central controller 3 identifies an overnight charge situation when it detects that an external voltage source has been connected to the vehicle and the vehicle ignition switch is in the off position. The central controller 3 activates a main charger 5 connected to lines A,B to charge the batteries. The charge current is gradually increased until the charger reaches its maximum output or until any individual battery voltage reaches 14.7 volts. Above this voltage it is envisaged that a battery will be overcharging with some of the energy supplied being consumed in unwanted overcharge reactions that amongst other things causes gassing which results in plate damage, 10 reduced liquid level and reduced battery life.

During the overnight charge process the central controller 3 is continually receiving updates of individual battery voltages and group temperature information and dynamically controlling the charge current of the main charger to ensure the maximum 15 individual battery voltage is no higher than 14.7 volts. Eventually the main charger output will reduce until it is merely maintaining a float voltage of 14.7 volts. This strategy is continued until the charger is switched off.

During the overnight charge the central controller 3 also initiates localised equalisation 20 charge, or discharge, of individual batteries. The remote management units 1 undertake this charge, or discharge. Within each battery group G1 to G8 the individual battery with the highest voltage above 14.6 volts is connected to the discharge resister for one minute. At the end of the one-minute period the next individual battery with the highest voltage above 14.6 volts is connected to the discharge resister for a period of one 25 minute. This may or may not be the same battery. This process is repeated within each battery group G1 to G8 until all individual battery voltages within the groups are below 14.6 volts.

After reducing all battery voltages to below 14.6 volts the local charger 7 is used to 30 boost the charge of any individual battery having a voltage below 14.5 volts. The battery with the lowest voltage is connected to the local charger 7, which supplies a boost charge for a 15 minute period. This is repeated for the next lowest voltage battery until all battery voltages are above 14.5 volts.

It is envisaged that the central controller 3 will issue a command to each micro controller 6 indicating which battery is to be connected to the discharge resistor 10 or charger 7, and will time the period and issue the disconnect command. However, it will be apparent that these decisions may be made within the local micro-controller 6.

5

- Equalisation of individual 12-volt batteries can also be accomplished without the benefit of an external power supply or auxiliary power unit. It is envisaged that local chargers 7 may be capable of supply from the main battery DC supply and utilise this to boost the charge on an individual battery showing a low state of charge as indicated by its terminal voltage. For an individual battery having a high state of charge the discharge register 10 can be used to lower its state of charge.

- The central controller 3 detects the in-use condition when the vehicle ignition is in the on position and there is no external supply connected to the vehicle. In this condition the central controller 3 attempts to maintain a constant state of charge for the battery using the auxiliary power unit. It is during this in-use period that most damage of the batteries can occur from either overcharging or over-discharge. The central controller 3 attempts to maintain the state of charge of the battery at a constant level of, say, 80%. This provides a safety margin for the battery to accept charge from regeneration in the electric motor or an overestimation of the output required from the auxiliary power unit (described later).

- The central controller 3 has dynamic control over the output power of the auxiliary power unit and dynamically controls this in order to meet the demands placed on the battery. The auxiliary power unit runs continuously during the in-use period and its power output is varied at, say, 5 minute intervals. There are a variety of ways of determining what the output of the auxiliary power unit should be during any 5 minute period. These might include using historical data tables and/or fuzzy logic models. However, one method that has worked adequately is for the central controller 3 to record the power consumption during the immediately proceeding 5 minute period and set the auxiliary power unit output to replace this energy during the next 5 minute period. If this estimation scheme is initiated from a known state of charge and managed correctly it should only be necessary to dynamically vary the auxiliary power

unit output to account for any over estimation or shortfall in the immediately preceding 5 minute period.

If the batteries have been well charged, and equalised, during overnight charging, and 5 thus have similar capacity, then good battery balance should be maintained throughout a days running without any equalisation being applied. However, if the central controller 3 detects that any individual cell voltage is outside an acceptable range it can initiate a localised boost charge or discharge via the remote management units as previously described. In use however the threshold voltage levels for the equalisation 10 procedure are reduced as appropriate.

In an electric vehicle braking or coasting will cause regeneration in the electric motor. During normal driving, say in any 5 minute period, there will be a certain amount of regeneration. This can be accounted for by reducing the auxiliary power unit output 15 estimation and the energy from regeneration supplied back to the batteries. However, it is essential that a brake resistor is available for use during regenerative braking to prevent excessively high voltages appearing across the DC Bus (i.e. the battery nodes A and B). The brake resister can be turned on during braking if the DC Bus voltage exceeds some preset value. The preset value may be dynamically variable by the 20 central controller 3 based on individual battery voltages to avoid over voltage of any individual battery.

Turn on of the brake resister can be used as an indication that the auxiliary power unit output should be reduced.

25

Thus according to the above scheme there is a battery management system which regulates charging of hybrid vehicle batteries in order to avoid overcharging or excessive discharge and to minimise charge/discharge cycles. The system also allows for equalisation of individual batteries during overnight charge as well as in use. The 30 system maintains good battery equalisation and promotes efficiency and longer battery life.

Good equalisation of individual cells or batteries within a battery group avoids the situation of an individual cell or battery becoming overcharged or excessively discharged long before the whole group.

- 5 Where in the foregoing description reference has been made to particular elements or integers having known equivalents, then such equivalents are included as if individually set forth.

- 10 A particular example of the invention has been described and it is envisaged that improvements and/or modifications can take place without departing from the scope of the invention.

**CLAIMS:**

1. A battery management unit for managing the state of charge of a plurality of cells or batteries connected thereto including:
  - 5 a state of charge sensor for measuring the state of charge of the cells or batteries;
  - a charger for charging a cell or battery;
  - a discharger for discharging a cell or battery;
  - 10 a controller which receives state of charge information from the state of charge sensor and selectively connects the charger or the discharger to a cell or battery to dynamically maintain the state of charge of the cells or batteries within a predetermined range.
- 15 2. A battery management unit as claimed in claim 1 wherein the state of charge sensor measures the voltage of each cell or battery to determine the state of charge of each cell or battery.
- 20 3. A battery management unit as claimed in claim 2 wherein a voltage sensor measures the voltage of each cell or battery and the outputs of the voltage sensors are multiplexed to the controller.
4. A battery management unit as claimed in any preceding claim including a temperature sensor for measuring the temperature of the cells or batteries and providing temperature information to the controller.
- 25 5. A battery management unit as claimed in any one of the preceding claims wherein the controller charges and discharges selected cells or batteries so as to maintain the state of charge of the cells or batteries within a desired range.
6. A battery management unit as claimed in claim 5 wherein the cell or battery having the lowest terminal voltage, below a predetermined low voltage threshold, is connected to the charger for a predetermined period until all cells have a terminal voltage above the low voltage threshold.
- 30 7. A battery management unit as claimed in any proceeding claim wherein the battery or cell having the highest terminal voltage, above a predetermined high voltage threshold, is connected to the discharger for a predetermined period until all cells have a terminal voltage below the high voltage threshold..

8. A battery management unit as claimed in any one of the proceeding claims including a power sensor for monitoring the power supplied by the charger to a cell or battery and supplying the information to the controller.
9. A battery management unit as claimed in any preceding claim wherein the controller includes a relay matrix for selectively connecting output terminals of the charger or discharger across the selected cell or battery.
10. A battery management unit as claimed in any one of the proceeding claims including a communications port for facilitating communication of battery information to a central control unit and for receiving commands from the central control unit to control the charging or discharging of selected cells or batteries.
11. A battery management system comprising a plurality of battery management units as claimed in any one of the proceeding claims and a central control unit, the battery management units being in communication with the central control unit via respective communication paths.
12. A system as claimed in claim 11 including a main charger for simultaneously charging a plurality of cells or batteries associated with a selected battery management unit in response to control commands from the central control unit.
13. A system as claimed in claim 11 or claim 12 including a generator responsive to the central control unit to charge selected cells or batteries associated with a battery management unit.
14. A system as claimed in claim 13 wherein the central control unit estimates the energy removed from the battery groups during a predetermined period and dynamically varies the supply of power to cells or batteries associated with selected battery management units to maintain substantially equal states of charge of the battery groups.
15. A system as claimed in any one of claims 11 to 14 wherein the central control unit receives state of charge information from each battery management unit and controls the local charging and discharging of selected cells or batteries via commands to the battery management units sent over the communication medium.
16. A system as claimed in any one of claims 11 to 14 wherein each individual battery management unit controls the charging and discharging of cells or batteries to maintain the states of charge of its associated cells or batteries within a prescribed range.

17. A method of charging and equalising the state of charge of a plurality of cells or batteries comprising the steps of:  
simultaneously charging the cells or batteries by a main charger; and  
maintaining the charged state of individual cells or batteries during  
5 charging by selectively charging or discharging cells having a state of charge outside of a prescribed range.
18. A method as claimed in claim 17 wherein the state of charge of each cell or battery is determined by measuring the voltage of each cell or battery.
19. A method as claimed in claim 18 wherein the battery having the highest terminal  
10 voltage, above a high voltage threshold, is discharged for a predetermined period until all cells or batteries are below the high voltage threshold.
20. A method as claimed in claim 18 or claim 19 wherein the cell or battery having the lowest terminal voltage, below a low voltage threshold level, is charged by a secondary charger until all cells or batteries have a terminal voltage above the  
15 low voltage threshold level.
21. A method as claimed in any one of claims 17 to 20 wherein the temperature of the cells or batteries is monitored and battery charging or discharging is controlled so that cell or battery temperature does not exceed the predetermined threshold.
- 20 22. A method as claimed in any one of claims 17 to 21 wherein a plurality of groups of batteries are simultaneously charged so as to maintain all cells or batteries within a desired range of state of charge.
23. A method as claimed in any one claims 17 to 22 wherein a plurality of battery management units monitor the state of charge of each associated cell or battery  
25 and a supply state of charge information to a central controller which controls the charging or discharging of cells or batteries according the state of charge information.
24. A method as claimed in claim 23 wherein the central controller selectively connects the output of a generator to selected cells or batteries based on power usage of the cells or batteries over a preceding period.  
30
25. A method as claimed in claim 24 wherein the central controller monitors power consumption for a predetermined period and connects with generator to selected cells or batteries so as to replace the amount of energy consumed during the preceding period.

26.A method as claimed in any one of claims 17 to 25 wherein the central control unit controls all charging and discharging of the cells or batteries.

27.A method as claimed in any one of claims 17 to 25 wherein the central control unit controls the charging of groups of cells or batteries via the main charger or generator and battery management units control the charging and discharging of individual cells or batteries independently.  
5

28.An electric vehicle including a battery management unit or system as claimed in any one of claims 1 to 16.

1/2

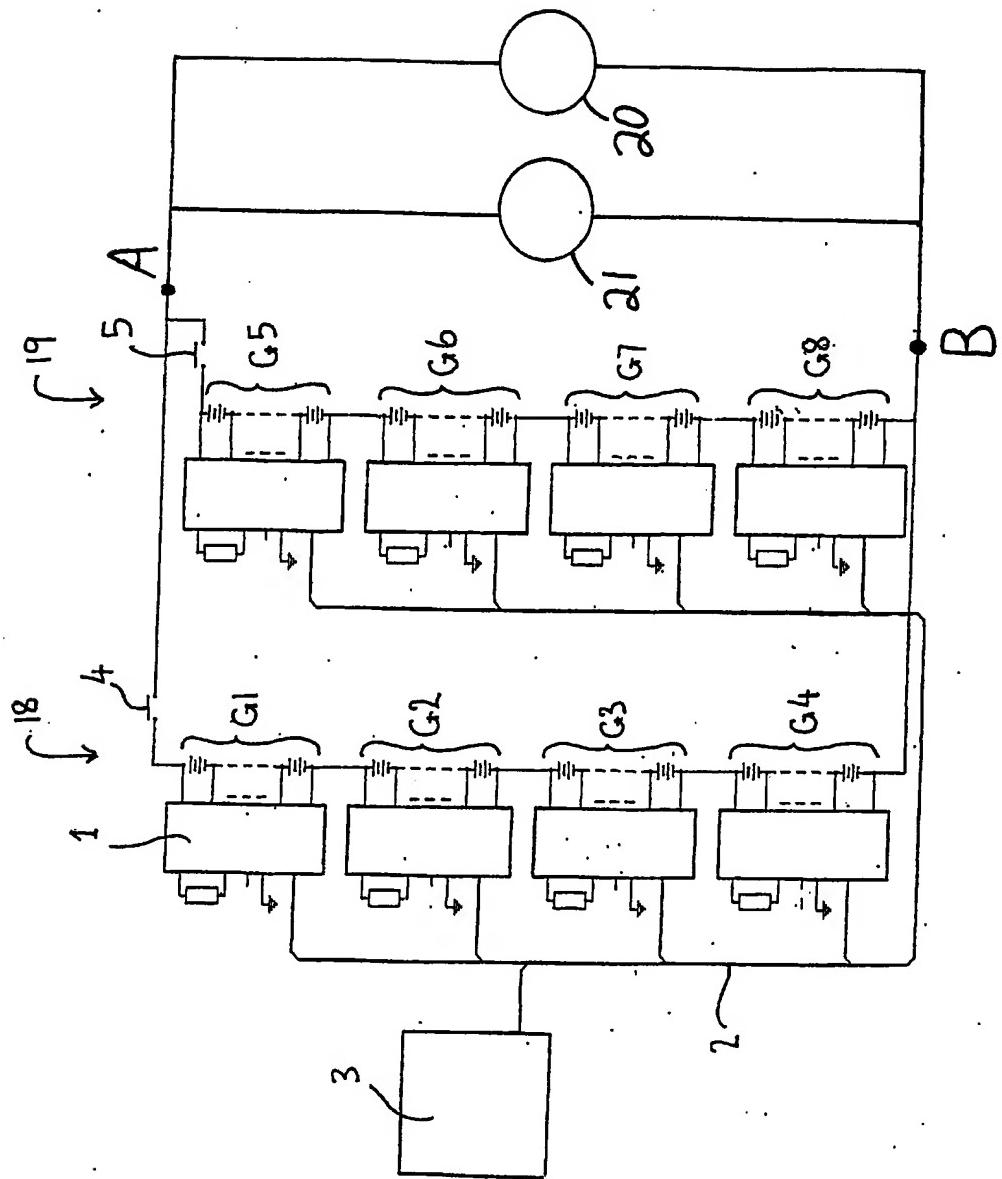


FIGURE 1

2/2

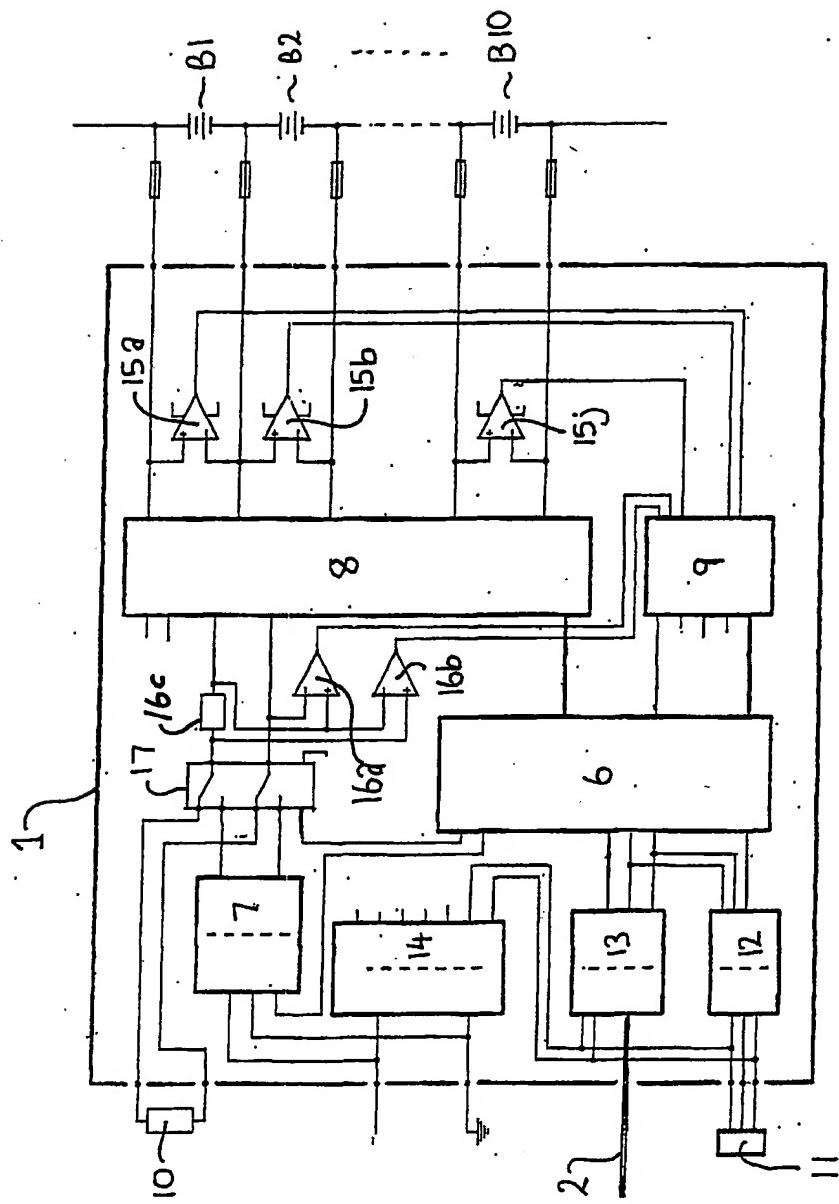


FIGURE 2

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/NZ02/00046

<b>A. CLASSIFICATION OF SUBJECT MATTER</b>		
Int. Cl. <sup>7</sup> : H02J 7/00		
According to International Patent Classification (IPC) or to both national classification and IPC		
<b>B. FIELDS SEARCHED</b>		
Minimum documentation searched (classification system followed by classification symbols)		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) WPAT (+charge+, cell or battery, balanc+, equal+, SOC)		
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
*L,X	"A Review of Cell Equalization Methods for Lithium Ion and Lithium Polymer Battery Systems" (Moore et al.) SAE 2001 World Congress March 5-8 , 2001 * A similar article to the above article was presented by the same authors at the 2001 SAE World Congress on the specified date. See also; <a href="http://web.archive.org/web/20010620063334/http://www.formulasun.org/asc/tech/SAE_2001-01-0959.pdf">http://web.archive.org/web/20010620063334/http://www.formulasun.org/asc/tech/SAE_2001-01-0959.pdf</a>	1,17
X	FR 2 797 096 (Sanyo Electric Co. Ltd.) 2 February 2001 Abstract, figures	1,2,17,18,20
Y		1-4,7,21,22
X	US 6 114 835 (Price) 5 September 2000 Whole document	1-3
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C		<input checked="" type="checkbox"/> See patent family annex
<p>* Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier application or patent but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"&amp;" document member of the same patent family</p>		
Date of the actual completion of the international search 29 May 2002	Date of mailing of the international search report - 7 JUN 2002	
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized officer  DALE E. SIVER Telephone No : (02) 6283 2196	

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/NZ02/00046

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 863 598 (Northrup Grumman Corporation) 9 September 1998 Abstract, figures	1,17
X	WO 95/15604 (Electronic Power technology, Inc.) 8 June 1995 Whole document	17,18,21-23
Y		1-4,8
X	EP 588 615 (Sony Corporation) 23 March 1994 Abstract, figures	1,2
Y	GB 2 337 166 (Ford Motor Company) 10 November 1999 Abstract, Claims	1,17
Y	EP 953 472 (Lockheed Martin Corporation) 3 November 1999 Abstract	1,17,28
Y	EP 807 546 (Toyota Jidosha Kabushiki Kaishi) 19 November 1997 Abstract	1,17
A	US 5 578 915 (Crouch, Jr. et al.) 26 November 1996 Abstract, claims	28
A	WO 96/22625 (Norvik Traction Inc.) 25 July 1996 Abstract	28

## INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/NZ02/00046

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report				Patent Family Member			
FR	2797096	DE	10035959	GB	2354892	JP	2001045672
		US	6373226				
US	6114835	NO	MEMBERS				
EP	863598	US	5900716				
WO	9515604	AU	13005/95	US	5504415		
EP	588615	EP	721247	JP	6105457	US	5530336
		JP	6105458				
GB	2337166	AU	31801/99	CA	2320489	EP	1061950
		WO	9939735	ZA	9900912		
EP	953472	BR	9901400	CN	1238588	JP	2000059916
		US	6091228				
EP	807546	JP	9308013	US	5883496		
US	5578915	NONE					
WO	9622625	US	5511084	AU	43815/96	CA	2184578
		EP	750804	US	5670861	US	5773962
		EP	664587	JP	7221399		

END OF ANNEX

12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT  
COOPERATION TREATY (PCT)

(11) WO 02/080332

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(54) BATTERY MANAGEMENT UNIT, SYSTEM AND METHOD

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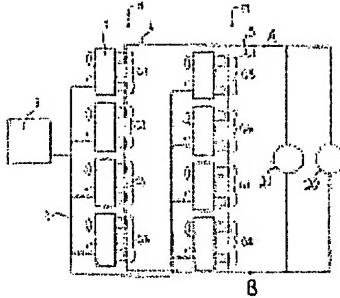
(81) AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO,  
CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR,  
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Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent  
(AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE,  
TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE,  
SN, TD, TG)

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**Published**

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(57) A battery management unit and system for managing the state of charge of cells or batteries (B1-B10). Each battery management unit (1) measures cell or battery terminal voltage and provides this information to a central controller (3) via a communication medium (2). Each battery management unit (1) monitors a plurality of batteries (B1-B10) and can selectively charge a selected battery (B1-B10) via a charger (7) and switch circuit (8, 17) or can selectively discharge a selected battery (B1-B10) via a load (10) and switch circuit (8, 17) under the control of a controller (6). The controller (6) may control charging and discharging in accordance with measurements from voltage sensors (15a-j) or may convey information from voltage sensors (15a-15j) to the central controller (3) and receive charging and discharging commands from the central controller (3). Charging and discharging is controlled to maintain all batteries within a desired state of charge ranged. The central controller (3) may selectively connect a main charger (20) or generator (21) to a bank of batteries associated with a battery management unit (1).

#### Description Claims

**Battery Management Unit, System and Method Field of the Invention** The invention relates to battery management systems and in particular to a system and method for managing the operation of batteries in electric vehicle applications.

**Background to the Invention** Electric vehicles are known in the art. They include one or more battery that supplies energy to one or more electric motors that in turn provide motive force to the vehicle.

Each battery is generally charged overnight for use during the day. In these vehicles each battery can undergo regular deep cycling of its state of charge and thus each battery life expectancy is typically short. It is undesirable to discharge a battery too far as this also shortens battery life.

Hybrid electric vehicles are known. One type of hybrid vehicle includes an auxiliary power unit that can be used to generate energy during use of the vehicle. This energy can be used to supplement battery energy or to charge the battery. With the availability of an auxiliary power unit within the vehicle it is desirable to have a battery management system which regulates battery and auxiliary power unit operation and avoids overcharging of the batteries, which can reduce battery life.

A number of battery management systems are known, however they generally only perform any real control during overnight charging. During use the auxiliary power unit is often run continuously at a predetermined and fixed power output. This can result in overcharging of the battery. Alternative schemes only run the auxiliary power unit if the battery voltage, or

state of charge, falls below a predetermined level. This does not overcome problems with state of charge cycling.

In the publication "Distributed VRLA Battery Management Organisation with Provision for Embedded Internet Interface" (Anbuky et AL.) IEEE, Telecommunications Energy Conference (INTELEC 2000) there is disclosed a distributed system for gathering and storing state of charge information. Data analysis is distributed rather than centralised and there is no disclosure of a charging strategy to achieve state of charge equalisation.

WO 99/01918 discloses a battery management system in which individual cells may be selectively connected to a single cell battery charger or a variable load bank. However, connection to the single cell battery charger or variable load link is simply for determining the capacity of each battery rather than for performing any equalisation of the state of charge of batteries.

US5701068 discloses a battery management system in which each battery has an associated battery module for monitoring the battery and charging the battery. This is an expensive and complex system.

US6043628 discloses a battery management system in which a bypass arrangement is provided for each battery to reduce overcharging of selected batteries whilst allowing the remaining batteries to be charged. This requires an individual module with a bypass resistor arrangement for each cell and does not allow the selective charging of selected batteries.

US6078165 is a system for monitoring and charging only. No discharge capability is disclosed.

EP0798839A2 discloses a battery management system in which an individual battery module is required for each battery making it expensive and complex.

It is an object of the present invention to provide a battery management system that controls battery operation in a hybrid electric vehicle to optimise battery performance and extend the battery life.

It is a further object of the present invention to provide a battery management system for hybrid electric vehicles that overcomes, or at least ameliorates, the above mentioned problems with the prior art.

The above objections are to be read disjunctively with the object of at least providing the public with a useful alternative.

**Summary of the Invention** According to a first aspect of the invention there is provided a battery management unit for managing the state of charge of a plurality of cells or batteries connected thereto including : a state of charge sensor for measuring the state of charge of the cells or batteries; a charger for charging a cell or battery; a discharger for discharging a cell or battery; a controller which receives state of charge information from the state of charge

sensor and selectively connects the charger or the discharger to a cell or battery to dynamically maintain the state of charge of the cells or batteries within a predetermined range.

According to a further aspect of the invention there is provided a method of charging and equalising the state of charge of a plurality of cells or batteries comprising the steps of: simultaneously charging the cells or batteries by a main charger; and ii maintaining the charged state of individual cells or batteries during charging by selectively charging or discharging cells having a state of charge outside of a prescribed range.

According to another aspect the invention provides for a system for managing the operation of a battery comprising two or more series connected cell or battery groups including : two or more battery management units connected to an associated battery group, the local apparatus including a local processor operable to measure one or more cell and/or ambient variable parameters and control charge and/or discharge of the one or more cells or batteries within the group; and a central processor in communication with two or more local processors; and wherein, the central processor is responsive to one or more cell and/or ambient variable parameters to dynamically control the supply of energy to the two or more series connected battery groups; and/or local processors are responsive to one or more cell and/or ambient variable parameters or transmitted control data to control charge and/or discharge of the one or more cells or batteries within a group substantially independently of the supply of energy to the two or more series connected battery groups.

Preferably the system includes a main charger, the central processor dynamically controlling the supply of energy to the two or more series connected battery groups via the main charger.

Preferably the system includes an auxiliary power unit, alternatively the central processor dynamically controlling the supply of energy to the two or more series connected battery groups via the auxiliary power unit. More preferably the central processor either continuously or periodically estimates the energy removed from the two or more series connected battery groups and dynamically varies the auxiliary power unit output power to substantially maintain a substantially constant state of charge of the two or more series connected battery groups.

According to a first particular aspect the invention provides for a system for managing the operation of a battery comprising two or more series connected cell or battery groups including: two or more battery management units, each connected to an associated battery group, the unit including : A local charger, A local discharger, A switch for electrically connecting the local charger or local discharger individually to one or more cells or batteries within the group, sensors for measuring one or more cell and/or ambient variable parameters within the group, and a local processor in communication with the local charger, discharger, switch, and sensors and being operable to control the charger, discharger and switch; a main charger for supplying energy to the two or more series connected battery groups; and a central processor in communication with two or more units and the main charger and being responsive to battery condition to manage operation of the battery.

Preferably the system includes a common communication medium, the central processor and local processors being connected to the common communication medium and each processor being operable to communicate with another processor or simultaneously to all processors connected to the medium.

Preferably the central processor is in communication with one or more local processor to receive information about one or more cell and/or ambient variable parameters and being responsive to said information to manage operation of the battery.

The central processor may be responsive to individual cell and/or variable parameters to manipulate the supply of energy from the main charger means to the two or more series connected battery groups, and/or transmit control data to one or more local processor dictating control of the one or more cells or batteries within the groups. Alternatively, the central processor may manipulate the supply of energy from the main charger to the two or more series connected battery groups and the local processor means may be responsive to reference information to control of the one or more cells or batteries within the groups.

Preferably the local processor can manipulate the supply AND/OR removal of energy to/from AN, individual cell or battery within its group independent of operation of any other group or the main charger. It is envisaged that preferably, although not exclusively, the switch is a multiplexer adapted to connect either the local charger or local discharge to any individual cell or battery within the group, the multiplexer being manipulated by the local processor.

According to a further aspect the invention provides for a method for managing the operation of a battery comprising two or more series connected cell or battery groups including : connecting a battery management unit to each of two or more battery groups, each said unit including : a local charger, a local discharger, a connector for electrically connecting the local charger or local discharger individually to one or more cells or batteries within the group, local sensors for measuring one or more cell and/or ambient variable parameters within the group, and a local processor in communication with the charger, discharger, connector, and sensor and being operable to control operation of said means and the one or more cells or batteries within the group; connecting a main charger to the battery; providing a central processor in communication with the unit; and wherein periodically or continuously the two or more unit measure one or more cell and/or ambient variable parameters of the two or more series connected battery groups and communicate said parameters to the central processor; and relating said parameters to reference criteria and in response the central processor dynamically controls the supply of energy to the two or more series connected battery groups; AND/OR local processor manipulates the charge and/or discharge of the one or more cells or batteries within a group substantially independently of the supply of energy to the two or more series connected battery groups Preferably the central processor initiates the measuring of one or more cell and/or ambient variable parameters and the communication of said parameters to the central processor.

Preferably the central processor initiates and terminates the charge or discharge of one or

more cells of batteries within a group.

Preferably the system includes a main charger, the central processor dynamically controlling the supply of energy to the two or more series connected battery groups via the main charger.

Preferably the system includes an auxiliary power unit, alternatively the central processor means dynamically controlling the supply of energy to the two or more series connected battery groups via the auxiliary power unit. More preferably the central processor either continuously or periodically estimates the energy removed from the two or more series connected battery groups and dynamically varies the auxiliary power unit output power to substantially maintain a substantially constant state of charge of the two or more series connected battery groups.

According to a further aspect the invention provides for a hybrid electric vehicle including a battery management system or method as hereinbefore defined.

Further aspects of the invention will become apparent from the following description which is given by way of example only.

**Brief Description of the Drawings** The invention will now be described with reference to the accompanying drawings in which: Figure 1; illustrates a schematic overview of the hardware from a battery management system according to the invention, and Figure 2 illustrates a schematic overview of a remote management unit of the battery management system illustrated in Figure 1.

**Description of the Preferred Example** A specific example of the invention will now be described with reference to Figures 1 and 2, in which like numerals represent like integers. The invention will be described with reference to a particular set-up of a hybrid electric vehicle in which the battery comprises two parallel strings 18 and 19 of forty series connected 12-volt batteries.

This is not critical to the invention, however, and it will become apparent to the skilled addressee that the invention is equally applicable to other battery configurations.

Referring to Figure 1, there shown is a schematic overview of the hardware from a battery management system according to the invention. The battery comprises eighty 12-VOLT batteries configured in two parallel strings 18 and 19 of forty series connected 12-volt batteries. Each string 18 and 19 is further divided into four groups G1-G4 and G5-G8 comprising ten series connected 12-volt batteries. According to this battery configuration the output voltage between Bus nodes A and B is 480-volts DC. Relays 4 and 5 allow isolation of each 480-VOLT battery string 18 and 19.

In communication with each ten battery group is a battery management unit 1, which for the purpose of this description shall be referred to as a remote management unit 1.

Each remote management unit 1 is connected to an RS485 communications medium 2,

typically in the form electrical conductors. Also connected to the communications medium 2 is a central controller, typically a programmable logic controller.

The system also includes a main battery charger 20 and an auxiliary power unit 21, both of known type, connected to the DC Bus nodes A and B. The main battery charger and auxiliary power unit are controllable by central controller 3.

Referring to Figure 2, there is shown a schematic overview of the hardware within a remote management unit 1. Each remote management unit 1 includes a local battery charger 7 and discharger, in eth form of discharge resistor 10, either of which can be electrically connected, via a multiplexer relay 8, to any one of batteries B1 to B10 within the corresponding battery group. A relay 17 is operable to electrically connect either of battery charger 7 or discharge resistor 10 to the common input of multiplexer relay 8, which in turn is operable to electrically connect its common input to any one of ten outputs corresponding to the ten batteries B1 to B10. Both relay 17 and multiplexer relay 8 are controlled by a local micro-controller 6. Thus charger 7 or discharge resistor 10 can be selectively connected across the terminals of any one of batteries B1 to B10.

The voltage of each battery in a group can be detected by differential amplifiers 15A to 15J. Two further differential amplifiers 16a and 16b (measuring the voltage drop across reference resistor 16c to determine current) are adapted to measure the voltage and current at the multiplexer relay 8 common input. An analogue multiplexer 9 is used to combine the outputs from each differential amplifier 15a to 15j, 16a and 16b, and scale their signal inputs into micro-controller 6. In the current embodiment the differential amplifiers are designed to measure voltages in the order of 0-16 volts which are scaled to 0-2. 5 volts at the micro-controller 6 analogue input.

A temperature probe 11 detects the common temperature of batteries B1 to B10 in the battery group. The temperature probe 11 signal is coupled to micro-controller 6 via an analogue isolation amplifier 12.

The micro-controller 6 can communicate with the central controller 3 via an RS485 interface 13 connected to communications medium 2. In the preferred embodiment the central controller 3 initiates all communications on medium 2. However, it is envisaged that in an alternative embodiment two or more micro-controllers 6 may communicate with each other.

Each remote management unit 1 includes a power supply module 14 that provides multiple voltage outputs to meet the power requirements of components within the remote management unit 1.

By the above configuration each remote management unit 1 has the ability to measure individual battery B1 to B10 voltages and the temperature of each battery group. This information is transmitted via communication medium 2 to central processor 3. The remote management unit 1 can also control local charge or discharge of any individual battery B1 to B10 within its group. This distributed data acquisition has the advantage of reducing the overall wiring needed to detect all eighty individual battery voltages directly at the central

controller 3, as well as the cost of additional controller 3 inputs.

In the preferred embodiment of the invention a number of communication transactions are envisaged that enable the central controller 3 and micro-controllers 6 from each remote management unit 1 to communicate the required information for charge management of the battery. The communication transactions are described below.

It is desirable, but not crucial to the invention, that individual battery voltages are measured simultaneously. While this is not possible within a battery group because of the use of multiplexing, it is envisaged that a remote management unit 1 will be able to consecutively sample each of its ten battery voltages within a few tens of milliseconds.

To ensure that each remote measurement unit 1 is synchronised to sample voltages simultaneously a "sample battery VOLTAGES" COMMAND is issued on the communications medium 2 by the central controller 3. The remote management unit 1 also samples the group temperature at this time.

The sampled battery voltages and temperature are stored in a data table within local micro-controller 6 memory. The data table also includes status information that will identify any fault conditions such as multiplexer relay failure, charger failure and the like. The central controller 3 polls each remote management unit 1, in turn, requesting that it transmit its information data table.

With access to individual battery information it is envisaged that the central controller 3 can make determinations on equalisation of individual batteries within a group. An "equalisation request" can be issued to an individual remote management unit 1 directing it to connect an individual battery to the local charger 7 or discharge resister 10 for equalisation purposes.

The following discussion relates to the scheme employed by the battery management system for management of the hybrid vehicle battery. As a preliminary point, individual battery voltages are sampled and transmitted to the central controller 3 at a rate of once every second. Also, the central controller 3 recognises two modes of operation: overnight charge control and in-use control.

The central controller 3 identifies an overnight charge situation when it detects that an external voltage source has been connected to the vehicle and the vehicle ignition switch is in the off position. The central controller 3 activates a main charger connected to lines A, B to charge the batteries. The charge current is gradually increased until the charger reaches its maximum output or until any individual battery voltage reaches 14.7 volts. Above this voltage it is envisaged that a battery will be overcharging with some of the energy supplied being consumed in unwanted overcharge reactions that amongst other things causes gassing which results in plate damage, reduced liquid level and reduced battery life.

During the overnight charge process the central controller 3 is continually receiving updates of individual battery voltages and group temperature information and dynamically controlling the charge current of the main charger to ensure the maximum individual battery

voltage is no higher than 14.7 volts. Eventually the main charger output will reduce until it is merely maintaining a float voltage of 14.7 volts. This strategy is continued until the charger is switched off.

During the overnight charge the central controller 3 also initiates localised equalisation charge, or discharge, of individual batteries. The remote management units 1 undertake this charge, or discharge. Within each battery group G1 to G8 the individual battery with the highest voltage above 14.6 volts is connected to the discharge resistor for one minute. At the end of the one-minute period the next individual battery with the highest voltage above 14.6 volts is connected to the discharge resistor for a period of one minute. This may or may not be the same battery. This process is repeated within each battery group G1 to G8 until all individual battery voltages within the groups are below 14.6 volts.

After reducing all battery voltages to below 14.6 volts the local charger 7 is used to boost the charge of any individual battery having a voltage below 14.5 volts. The battery with the lowest voltage is connected to the local charger 7, which supplies a boost charge for a 15 minute period. This is repeated for the next lowest voltage battery until all battery voltages are above 14.5 volts.

It is envisaged that the central controller 3 will issue a command to each micro controller 6 indicating which battery is to be connected to the discharge resistor 10 or charger 7, and will time the period and issue the disconnect command. However, it will be apparent that these decisions may be made within the local micro-controller 6.

EQUALISATION of individual 12-volt batteries can also be accomplished without the benefit of an external power supply or auxiliary power unit. It is envisaged that local chargers 7 may be capable of supply from the main battery DC supply and utilise this to boost the charge on an individual battery showing a low state of charge as indicated by its terminal voltage. For an individual battery having a high state of charge the discharge resistor 10 can be used to lower its state of charge.

The central controller 3 detects the in-use condition when the vehicle ignition is in the on position and there is no external supply connected to the vehicle. In this condition the central controller 3 attempts to maintain a constant state of charge for the battery using the auxiliary power unit. It is during this in-use period that most damage of the batteries can occur from either overcharging or over-discharge. The central controller 3 attempts to maintain the state of charge of the battery at a constant level of, say, 80%.

This provides a safety margin for the battery to accept charge from regeneration in the electric motor or an overestimation of the output required from the auxiliary power unit (described later).

The central controller 3 has dynamic control over the output power of the auxiliary power unit and dynamically controls this in order to meet the demands placed on the battery. The auxiliary power unit runs continuously during the in-use period and its power output is varied at, say, 5 minute intervals. There are a variety of ways of determining what the output of the

auxiliary power unit should be during any 5 minute period. These might include using historical data tables and/or fuzzy logic models.

However, one method that has worked adequately is for the central controller 3 to record the power consumption during the immediately proceeding 5 minute period and set the auxiliary power unit output to replace this energy during the next 5 minute period. If this estimation scheme is initiated from a known state of charge and managed correctly it should only be necessary to dynamically vary the auxiliary power unit output to account for any over estimation or shortfall in the immediately preceding 5 minute period.

If the batteries have been well charged, and equalised, during overnight charging, and thus have similar capacity, then good battery balance should be maintained throughout a day's running without any equalisation being applied. However, if the central controller 3 detects that any individual cell voltage is outside an acceptable range it can initiate a localised boost charge or discharge via the remote management units as previously described. In use however the threshold voltage levels for the equalisation procedure are reduced as appropriate.

In an electric vehicle braking or coasting will cause regeneration in the electric motor.

During normal driving, say in any 5 minute period, there will be a certain amount of regeneration. This can be accounted for by reducing the auxiliary power unit output estimation and the energy from regeneration supplied back to the batteries. However, it is essential that a brake resistor is available for use during regenerative braking to prevent excessively high voltages appearing across the DC Bus (i. e. the battery nodes A and B). The brake resistor can be turned on during braking if the DC Bus voltage exceeds some preset value. The preset value may be dynamically variable by the central controller 3 based on individual battery voltages to avoid over voltage of any individual battery.

Turn on of the brake resistor can be used as an indication that the auxiliary power unit output should be reduced.

Thus according to the above scheme there is a battery management system which regulates charging of hybrid vehicle batteries in order to avoid overcharging or excessive discharge and to minimise charge/discharge cycles. The system also allows for equalisation of individual batteries during overnight charge as well as in use. The system maintains good battery equalisation and promotes efficiency and longer battery life. Good equalisation of individual cells or batteries within a battery group avoids the situation of an individual cell or battery becoming overcharged or excessively discharged long before the whole group.

Where in the foregoing description reference has been made to particular elements or integers having known equivalents, then such equivalents are included as if individually set forth.

A particular example of the invention has been described and it is envisaged that improvements and/or modifications can take place without departing from the scope of the

invention.

Description Claims

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CLAIMS : 1. A battery management unit for managing the state of charge of a plurality of cells or batteries connected thereto including: a state of charge sensor for measuring the state of charge of the cells or batteries; a charger for charging a cell or battery ; a discharger for discharging a cell or battery; a controller which receives state of charge information from the state of charge sensor and selectively connects the charger or the discharger to a cell or battery to dynamically maintain the state of charge of the cells or batteries within a predetermined range.

2. A battery management unit as claimed in claim 1 wherein the state of charge sensor measures the voltage of each cell or battery to determine the state of charge of each cell or battery.

3. A battery management unit as claimed in claim 2 wherein a voltage sensor measures the voltage of each cell or battery and the outputs of the voltage sensors are multiplexed to the controller.

4. A battery management unit as claimed in any preceding claim including a temperature sensor for measuring the temperature of the cells or batteries and providing temperature information to the controller.

5. A battery management unit as claimed in any one of the preceding claims wherein the controller charges and discharges selected cells or batteries so as to maintain the state of charge of the cells or batteries within a desired range.

6. A battery management unit as claimed in claim 5 wherein the cell or battery having the lowest terminal voltage, below a predetermined low voltage threshold, is connected to the charger for a predetermined period until all cells have a terminal voltage above the low voltage threshold.

7. A battery management unit as claimed in any proceeding claim wherein the battery or cell having the highest terminal voltage, above a predetermined high, voltage threshold, is connected to the discharger for a predetermined period until all cells have a terminal voltage below the high voltage threshold.

8. A battery management unit as claimed in any one of the proceeding claims including a power sensor for monitoring the power supplied by the charger to a cell or battery and supplying the information to the controller.

9. A battery management unit as claimed in any preceding claim wherein the controller includes a relay matrix for selectively connecting output terminals of the charger or discharger across the selected cell or battery.

10. A battery management unit as claimed in any one of the proceeding claims including a communications port for facilitating communication of battery information to a central control unit and for receiving commands from the central control unit to control the charging or discharging of selected cells or batteries.
11. A battery management system comprising a plurality of battery management units as claimed in any one of the proceeding claims and a central control unit, the battery management units being in communication with the central control unit via respective communication paths.
12. A system as claimed in claim 11 including a main charger for simultaneously charging a plurality of cells or batteries associated with a selected battery management unit in response to control commands from the central control unit.
13. A system as claimed in claim 11 or claim 12 including a generator responsive to the central control unit to charge selected cells or batteries associated with a battery management unit.
14. A system as claimed in claim 13 wherein the central control unit estimates the energy removed from the battery groups during a predetermined period and dynamically varies the supply of power to cells or batteries associated with selected battery management units to maintain substantially equal states of charge of the battery groups.
15. A system as claimed in any one of claims 11 to 14 wherein the central control unit receives state of charge information from each battery management unit and controls the local charging and discharging of selected cells or batteries via commands to the battery management units sent over the communication medium.
16. A system as claimed in any one of claims 11 to 14 wherein each individual battery management unit controls the charging and discharging of cells or batteries to maintain the states of charge of its associated cells or batteries within a prescribed range.
17. A method of charging and equalising the state of charge of a plurality of cells or batteries comprising the steps of: simultaneously charging the cells or batteries by a main charger; and maintaining the charged state of individual cells or batteries during charging by selectively charging or discharging cells having a state of charge outside of a prescribed range.
18. A method as claimed in claim 17 wherein the state of charge of each cell or battery is determined by measuring the voltage of each cell or battery.
19. A method as claimed in claim 18 wherein the battery having the highest terminal voltage, above a high voltage threshold, is discharged for a predetermined period until all cells or batteries are below the high voltage threshold.
20. A method as claimed in claim 18 or claim 19 wherein the cell or battery having the lowest terminal voltage, below a low voltage threshold level, is charged by a secondary

charger until all cells or batteries have a terminal voltage above the low voltage threshold level.

21. A method as claimed in any one of claims 17 to 20 wherein the temperature of the cells or batteries is monitored and battery charging or discharging is controlled so that cell or battery temperature does not exceed the predetermined threshold.
  22. A method as claimed in any one of claims 17 to 21 wherein a plurality of groups of batteries are simultaneously charged so as to maintain all cells or batteries within a desired range of state of charge.
  23. A method as claimed in any one of claims 17 to 22 wherein a plurality of battery management units monitor the state of charge of each associated cell or battery and a supply state of charge information to a central controller which controls the charging or discharging of cells or batteries according to the state of charge information.
  24. A method as claimed in claim 23 wherein the central controller selectively connects the output of a generator to selected cells or batteries based on power usage of the cells or batteries over a preceding period.
  25. A method as claimed in claim 24 wherein the central controller monitors power consumption for a predetermined period and connects with generator to selected cells or batteries so as to replace the amount of energy consumed during the preceding period.
  26. A method as claimed in any one of claims 17 to 25 wherein the central control unit controls all charging and discharging of the cells or batteries.
  27. A method as claimed in any one of claims 17 to 25 wherein the central control unit controls the charging of groups of cells or batteries via the main charger or generator and battery management units control the charging and discharging of individual cells or batteries independently.
  28. An electric vehicle including a battery management unit or system as claimed in any one of claims 1 to 16.
- Description Claims
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- Claims
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- CLAIMS : 1. A battery management unit for managing the state of charge of a plurality of cells or batteries connected thereto including: a state of charge sensor for measuring the state of charge of the cells or batteries; a charger for charging a cell or battery; a discharger for discharging a cell or battery; a controller which receives state of charge information from the state of charge sensor and selectively connects the charger or the discharger to a cell or battery to dynamically maintain the state of charge of the cells or batteries within a

predetermined range.

2. A battery management unit as claimed in claim 1 wherein the state of charge sensor measures the voltage of each cell or battery to determine the state of charge of each cell or battery.
3. A battery management unit as claimed in claim 2 wherein a voltage sensor measures the voltage of each cell or battery and the outputs of the voltage sensors are multiplexed to the controller.
4. A battery management unit as claimed in any preceding claim including a temperature sensor for measuring the temperature of the cells or batteries and providing temperature information to the controller.
5. A battery management unit as claimed in any one of the preceding claims wherein the controller charges and discharges selected cells or batteries so as to maintain the state of charge of the cells or batteries within a desired range.
6. A battery management unit as claimed in claim 5 wherein the cell or battery having the lowest terminal voltage, below a predetermined low voltage threshold, is connected to the charger for a predetermined period until all cells have a terminal voltage above the low voltage threshold.
7. A battery management unit as claimed in any proceeding claim wherein the battery or cell having the highest terminal voltage, above a predetermined high, voltage threshold, is connected to the discharger for a predetermined period until all cells have a terminal voltage below the high voltage threshold.
8. A battery management unit as claimed in any one of the proceeding claims including a power sensor for monitoring the power supplied by the charger to a cell or battery and supplying the information to the controller.
9. A battery management unit as claimed in any preceding claim wherein the controller includes a relay matrix for selectively connecting output terminals of the charger or discharger across the selected cell or battery.
10. A battery management unit as claimed in any one of the proceeding claims including a communications port for facilitating communication of battery information to a central control unit and for receiving commands from the central control unit to control the charging or discharging of selected cells or batteries.
11. A battery management system comprising a plurality of battery management units as claimed in any one of the proceeding claims and a central control unit, the battery management units being in communication with the central control unit via respective communication paths.

12. A system as claimed in claim 11 including a main charger for simultaneously charging a plurality of cells or batteries associated with a selected battery management unit in response to control commands from the central control unit.
13. A system as claimed in claim 11 or claim 12 including a generator responsive to the central control unit to charge selected cells or batteries associated with a battery management unit.
14. A system as claimed in claim 13 wherein the central control unit estimates the energy removed from the battery groups during a predetermined period and dynamically varies the supply of power to cells or batteries associated with selected battery management units to maintain substantially equal states of charge of the battery groups.
15. A system as claimed in any one of claims 11 to 14 wherein the central control unit receives state of charge information from each battery management unit and controls the local charging and discharging of selected cells or batteries via commands to the battery management units sent over the communication medium.
16. A system as claimed in any one of claims 11 to 14 wherein each individual battery management unit controls the charging and discharging of cells or batteries to maintain the states of charge of its associated cells or batteries within a prescribed range.
17. A method of charging and equalising the state of charge of a plurality of cells or batteries comprising the steps of: simultaneously charging the cells or batteries by a main charger; and maintaining the charged state of individual cells or batteries during charging by selectively charging or discharging cells having a state of charge outside of a prescribed range.
18. A method as claimed in claim 17 wherein the state of charge of each cell or battery is determined by measuring the voltage of each cell or battery.
19. A method as claimed in claim 18 wherein the battery having the highest terminal voltage, above a high voltage threshold, is discharged for a predetermined period until all cells or batteries are below the high voltage threshold.
20. A method as claimed in claim 18 or claim 19 wherein the cell or battery having the lowest terminal voltage, below a low voltage threshold level, is charged by a secondary charger until all cells or batteries have a terminal voltage above the low voltage threshold level.
21. A method as claimed in any one of claims 17 to 20 wherein the temperature of the cells or batteries is monitored and battery charging or discharging is controlled so that cell or battery temperature does not exceed the predetermined threshold.
22. A method as claimed in any one of claims 17 to 21 wherein a plurality of groups of batteries are simultaneously charged so as to maintain all cells or batteries within a desired

range of state of charge.

23. A method as claimed in any one claims 17 to 22 wherein a plurality of battery management units monitor the state of charge of each associated cell or battery and a supply state of charge information to a central controller which controls the charging or discharging of cells or batteries according the state of charge information.
24. A method as claimed in claim 23 wherein the central controller selectively connects the output of a generator to selected cells or batteries based on power usage of the cells or batteries over a preceding period.
25. A method as claimed in claim 24 wherein the central controller monitors power consumption for a predetermined period and connects with generator to selected cells or batteries so as to replace the amount of energy consumed during the preceding period.
26. A method as claimed in any one of claims 17 to 25 wherein the central control unit controls all charging and discharging of the cells or batteries.
27. A method as claimed in any one of claims 17 to 25 wherein the central control unit controls the charging of groups of cells or batteries via the main charger or generator and battery management units control the charging and discharging of individual cells or batteries independently.
28. An electric vehicle including a battery management unit or system as claimed in any one of claims 1 to 16.

Description Claims